

THE NEAREST BLACK HOLES

NASA Grant NAG5-10889

Annual Report

For the Period 15 May 2001 through 14 May 2002

Principal Investigator
Dr. M. Garcia

April 2002

Prepared for:

National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

Smithsonian Institution
Astrophysical Observatory
Cambridge, Massachusetts 02138

<p>The Smithsonian Astrophysical Observatory is a member of the Harvard-Smithsonian Center for Astrophysics</p>

The NASA Technical Officer for this grant is Ronald J. Oliversen, 681.0, NASA/Goddard Space Flight Center, Greenbelt, Maryland 20771-0001

This is the first Annual Report for this 5-year LTSA program, and covers the period 5/15/01 to 3/02, (10.5 months) as the funds arrived from NASA somewhat later than anticipated.

The goal of this program is to study black holes, both in our Galaxy and in nearby galaxies. We aim to study both 'stellar mass' x-ray binaries containing black holes (both in our Galaxy and in nearby galaxies), and super-massive black holes in nearby galaxies. This program facilitates this study by funding related travel, computer equipment, and partial salary for a post-doc.

Travel:

In July 2001 this program supported a speaking tour of Astronomy Departments in England (St. Andrews University, Scotland; Leicester University, England; University of Southampton, England; Bristol University, England; Open University, Milton Keynes, England) where I delivered the colloquium 'Chandra Observations of very Black Black Holes'. Collaborations forged during this trip resulted in an XMM A02 proposal for ~500 ks worth of observations of quiescent Galactic black holes, in order to accurately measure their spectra. This colloquium has since also been delivered to the physics departments at Tufts U. and U. Mass Lowell.

This fund also supported a trip by our PostDoc (A. Kong) to the XMM conference to present a paper (see [astroph/202065](#) below).

Colloquium: "Chandra Observations of Very BLACK Black Holes."

In 1997, Narayan, Garcia and McClintock claimed that Black Hole X-ray Novae (BHXN) in quiescence are much less luminous than equivalent Neutron Star X-ray Novae (NSXN). This claim was based on the quiescent detection of a single short period BHXN (A0620-00, $P=7.8$ hrs) and two longer period BHXN (GRO J1655-40, $P=62.9$ hrs; V404 Cyg, $P=155.3$ hrs), along with sensitive upper limits. Chandra has allowed detection of two more short period BHXN (GRO J0422+32, $P=5.1$ hrs; GS 2000+25, $P=8.3$ hrs), an upper limit for a third which is improved by two orders of magnitude (4U 1543-47, $P=27.0$ hrs) and a new, much lower quiescent measurement of GRO J1655-40. Taken together, these new Chandra measurements confirm that the quiescent X-ray luminosities of BHXN are significantly lower than those of NSXN. We argue that this provides strong evidence for the existence of event horizons in BHXN. We are taking a first step in extending this study of galactic solar mass black holes to another galaxy, M31. Chandra has found many highly variable sources within M31, some of which may be BHXN. We have begun a coordinated Chandra and HST program to identify the UV-Optical counterparts of these transients in M31.

Publications:

This program has supported the analysis and publication of several papers, talks, and posters, including those listed below.

ASTRO-PH/0203243, submitted to ApJ

"X-ray Point Sources in The Central Region of M31 as seen by Chandra"
Albert K.H. Kong, Michael R. Garcia, Francis A. Primini,
Stephen S. Murray, Rosanne Di Stefano and Jeffrey E. McClintock

($L_x \sim 1.5 \times 10^{39}$ erg/s in the 0.3-8 keV band) about 4' North of the nucleus. We find another transient black-hole candidate ($L_x \sim 5 \times 10^{38}$ erg/s) about 5' North-West of the nucleus. The UV and X-ray counterparts of SN 2002ap are also found in this XMM observation.

2001 APJ astro-ph/0111134

The X-ray Spectra of Black Hole X-ray Novae in Quiescence as Measured Chandra

Albert K.H. Kong, Jeffrey E. McClintock, Michael R. Garcia, Stephen S. Murray

We present Chandra observations of black hole X-ray novae Cyg X-3, A0620-00, GRO J1655-40, and XTE J1550-564 in quiescence. Their quiescent spectra can be well fitted by a power-law model with number slope $\alpha \sim 2$. While a coronal (Raymond-Smith) model is also a statistically acceptable representation of the spectra, the best fit temperatures of these models is ~ 5 times higher than that seen in active stellar coronae. These four spectra of quiescent X-ray novae are all consistent with that expected for accretion via an advection-dominated accretion flow (ADAF) and inconsistent with that expected from a stellar corona. This evidence for continued accretion in quiescence further strengthens the case for the existence of event horizons in black holes. Both A0610-00 and GRO J1655-40 were fainter than in previous observations, while Cyg X-3 was more luminous and varied by a factor of 2 in a few ksec. A reanalysis of the X-ray data for XTE J1550-564 shows that (like Cyg X-3 and A0620-00) its luminosity exceeds the maximum prediction of the coronal model by a large factor. The 0.3-7 keV luminosity of the four sources studied ranges from $\sim 10^{30}$ - 10^{33} erg s $^{-1}$.

PostDoc:

We have hired Albert Kong, and are paying for his salary from a variety of sources. Albert came with some funding of his own via a Croucher Fellowship, which has allowed us to leverage the funds from this program and extend his stay here at the CfA. Albert's main emphasis has been on studies of black holes in nearby galaxies (rather than our Galaxy). As we planned in our LTSA proposal, we also hoped to acquire funding via NASA/GO programs in order to help support this program, and we have obtained some of that funding. This, along with Albert's Croucher Fellowship funding, may allow us to hire a post-doc who would concentrate more on studies of black holes with our Galaxy.